# Bridging the Research and Spaceflight Operations Gap: The Extra-vehicular Activity Infrared (EVA IR) Camera Experience

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***NASA Project Manager Challenge***

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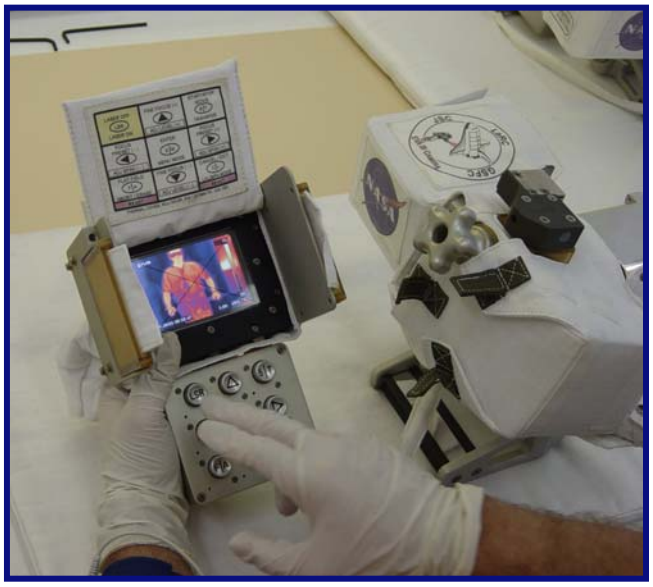
NASA Langley Research Center

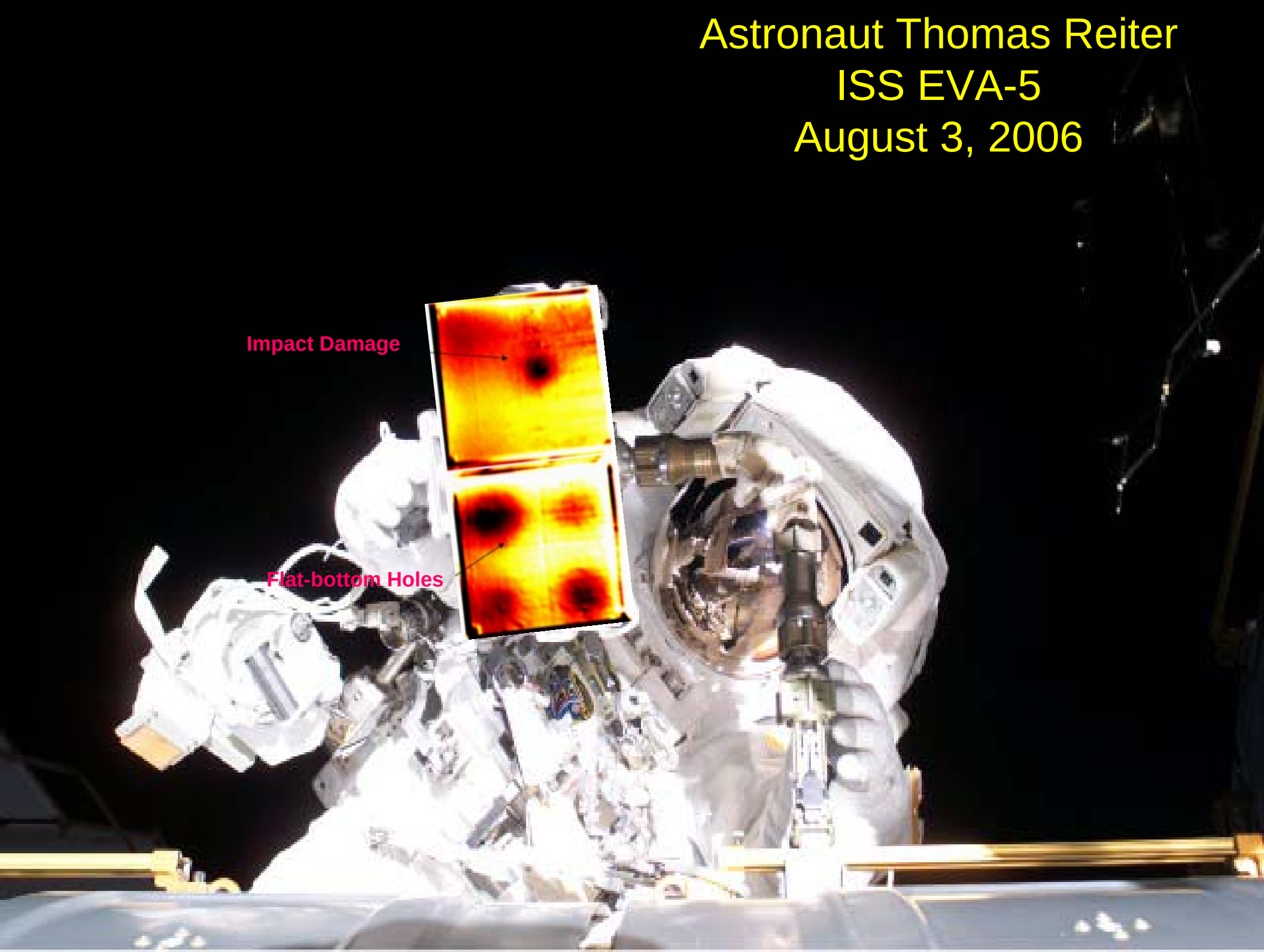
# Extra-vehicular Activity (EVA) Infrared (IR) Camera Provided New Capability to Shuttle Program

- Langley Research Center led the development of an EVA Infrared Camera that help astronauts remain safe by detecting damage to the orbiter wing leading edge

- The EVA Infrared Camera project combined Research and Development (R&D) expertise with Flight Hardware Development expertise

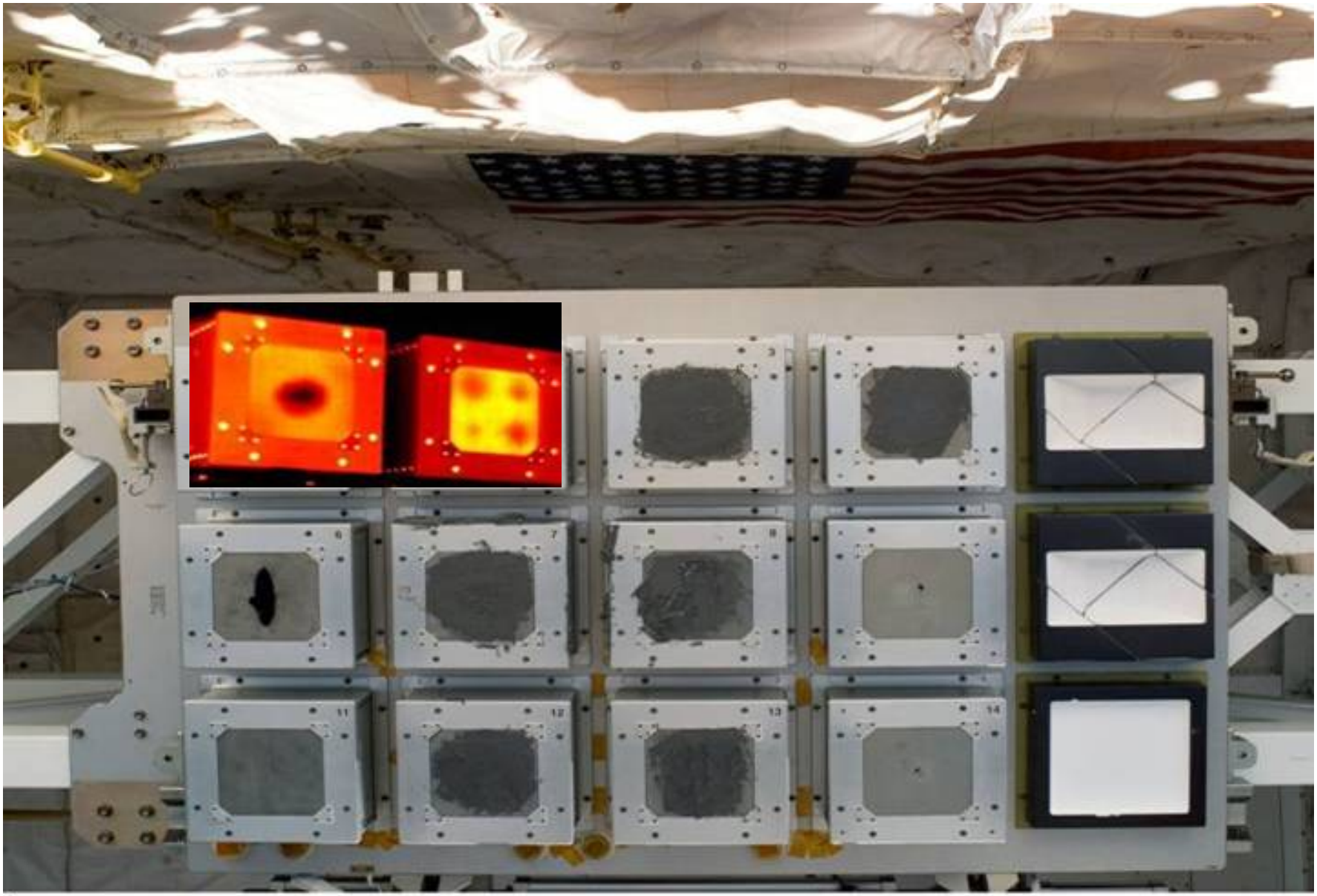



Astronaut Thomas Reiter
ISS EVA-5
August 3, 2006




ISS013E63434

# New Capability: Detect Sub-surface Damage
## STS-121 Mission Data from the Sample Box



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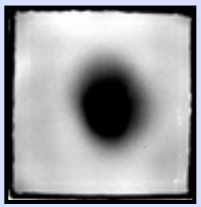
# Transitioning Ground Inspection to Orbital Inspection

## Ground Thermography System

- High Power
- High Weight



Ground Inspection:
RCC w/ Impact Damage

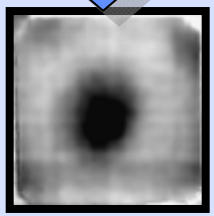
## On-orbit Thermography System

EVA IR Camera System

- Low Power
- Low Weight

&

LaRC Developed Ground Processing

EVA IR Camera Inspection
w/ LaRC Developed Processing:
RCC w/ Impact Damage

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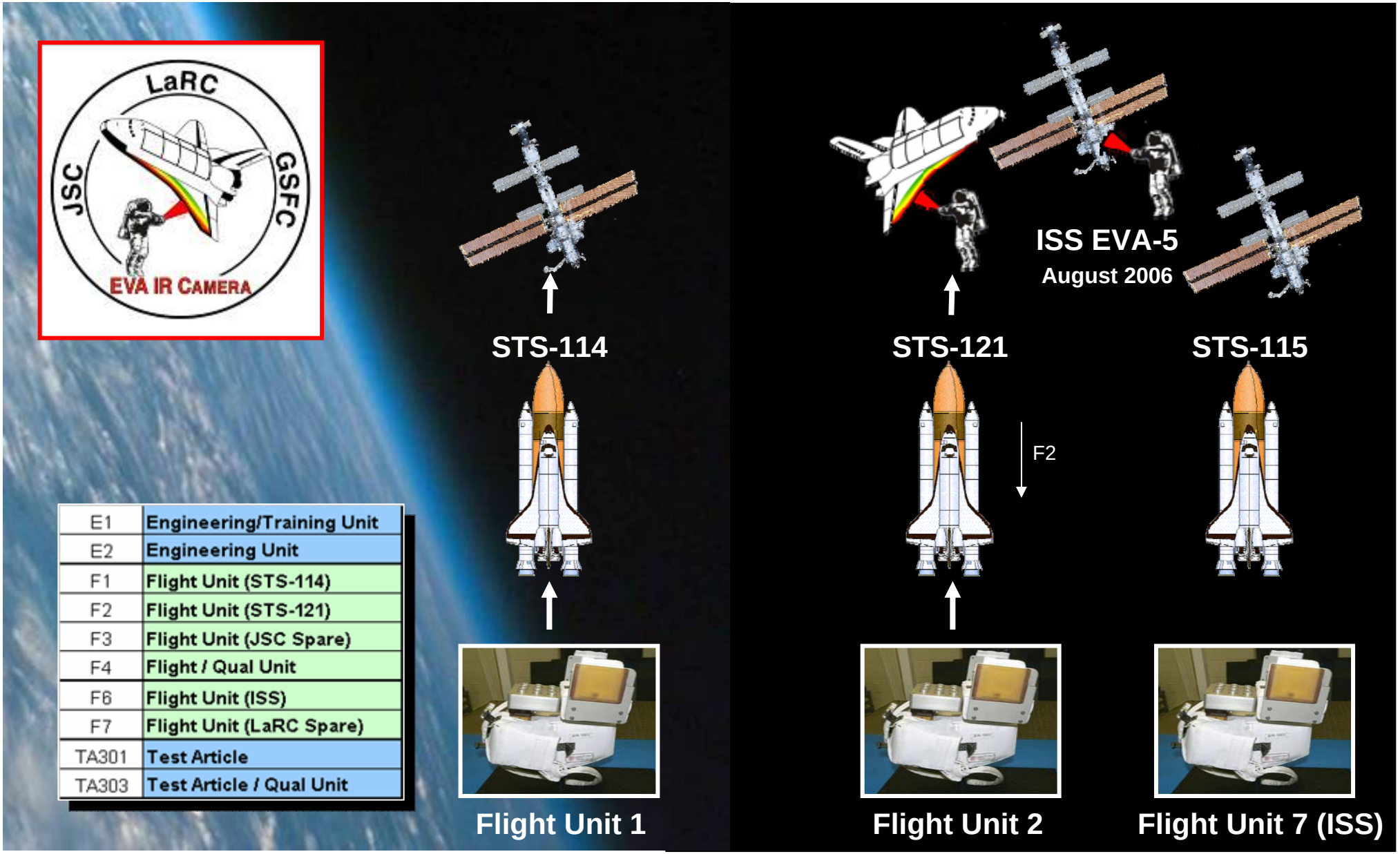
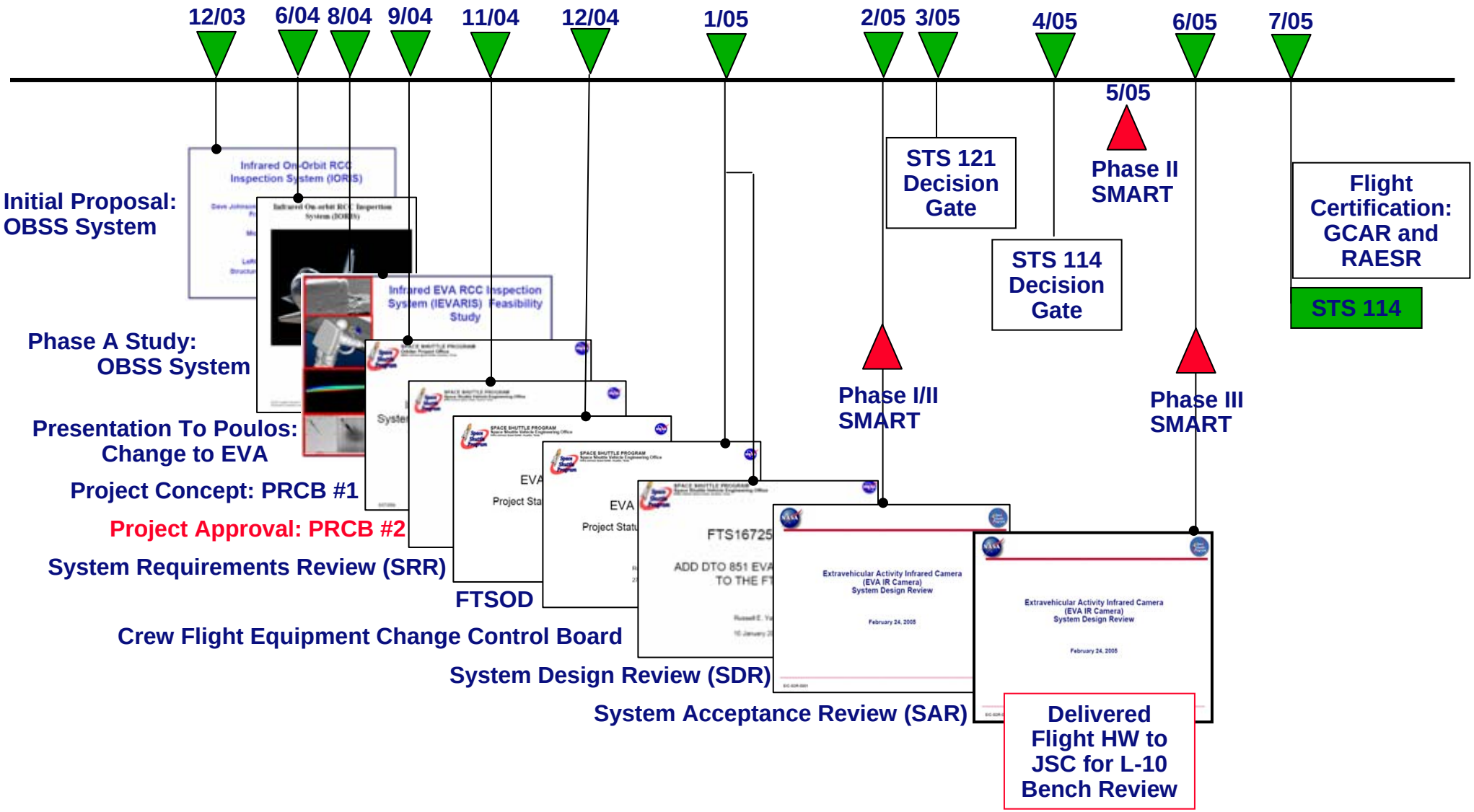
# EVA IR Camera Shuttle Program Support




| | |
|---|---|
| E1 | Engineering/Training Unit |
| E2 | Engineering Unit |
| F1 | Flight Unit (STS-114) |
| F2 | Flight Unit (STS-121) |
| F3 | Flight Unit (JSC Spare) |
| F4 | Flight / Qual Unit |
| F6 | Flight Unit (ISS) |
| F7 | Flight Unit (LaRC Spare) |
| TA301 | Test Article |
| TA303 | Test Article / Qual Unit |

July 2005 | July 2006 | Sept 2006

# Project Timeline: Major Milestones



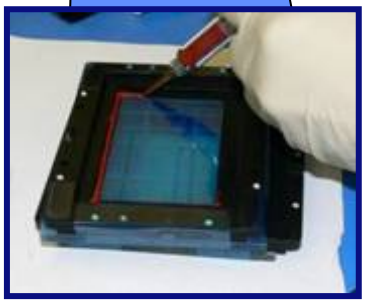
# Extensive Systems Engineering

Mechanical Systems


Electronic Systems

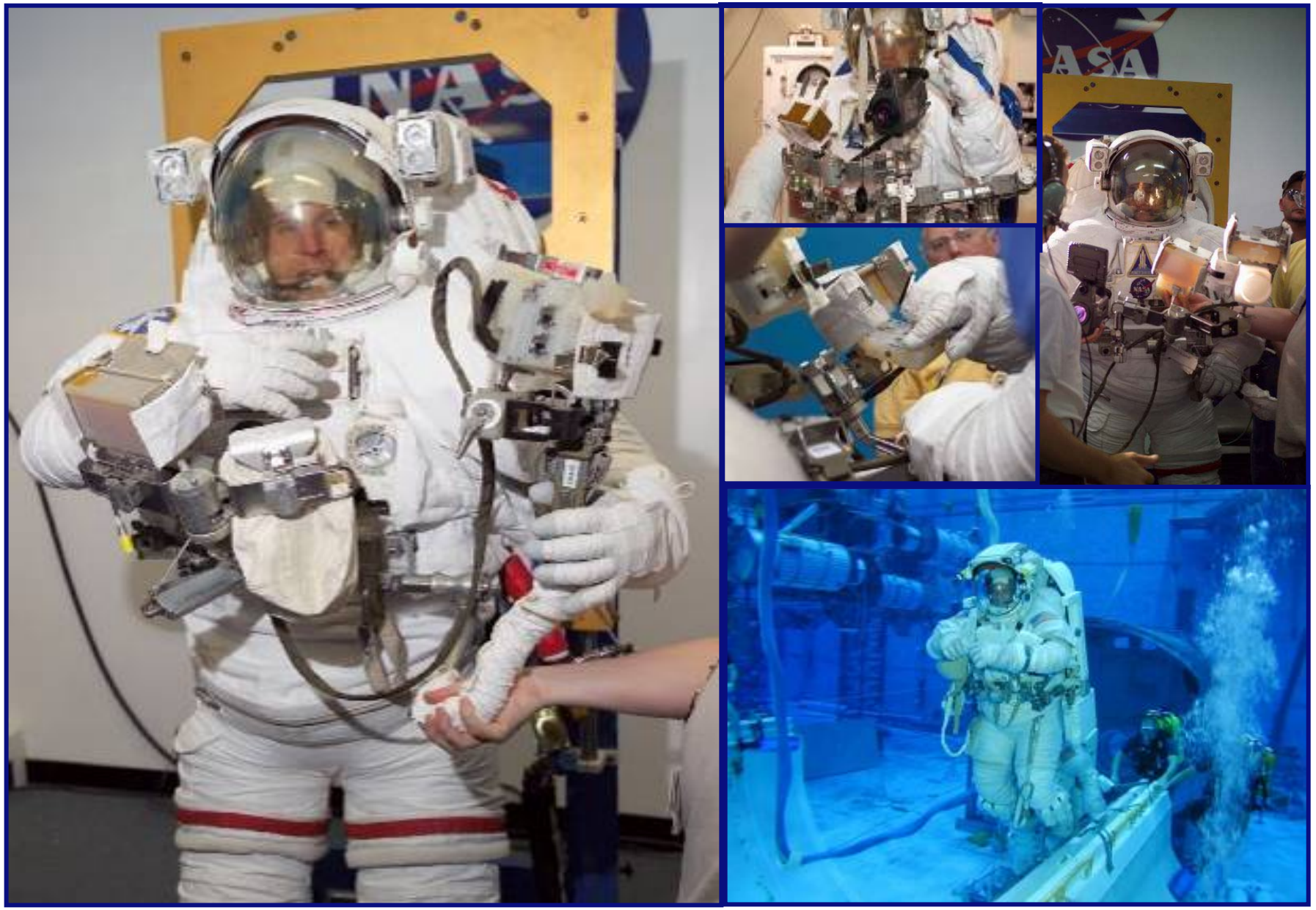
Firmware Systems


Thermal Systems



Display Systems

# Extensive Crew Evaluation

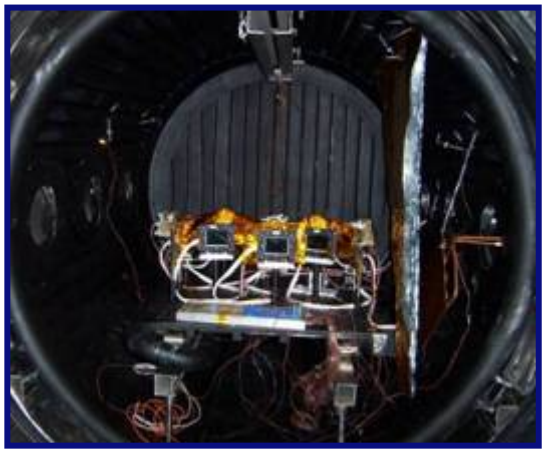


# Extensive Verification Testing at LaRC

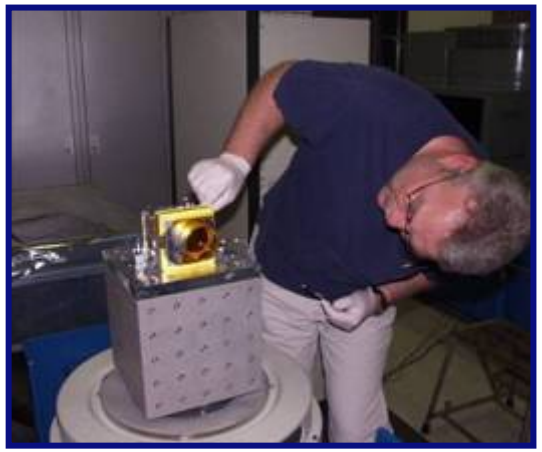
**ION Radiation**

**Power Cycle Burn-in**

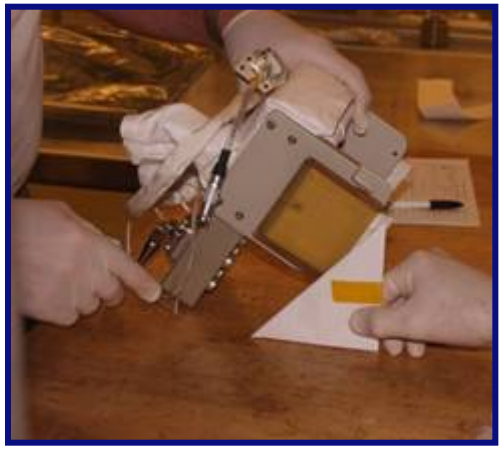
**Thermal Vacuum**



**Random Vibration**



**Shock**



**Bench Handling Drop & Packaged Drop**

**Electromagnetic Compatibility**

**Pre-Delivery Acceptance (PDA)**

# Research - Spaceflight Gap


- **Culture**
  - Researchers “Investigate to Learn”
  - Developers “Develop What is Required”
  - Operators “Want Tried and True”
- **Terminology**
  - Researchers “Test to Experiment and Learn”
  - Developers “Test to Reduce Risk”
- **Perception**
  - Researcher Views Spaceflight Operation as buying systems out-of-house with no technical expertise, a “process” house
  - Research Centers viewed as a library
- **Manner that work is done**
  - Researcher’s approach with goal of gaining knowledge
    - 10% defending, 90% doing
  - Developer only performs what is required, tasks must come with a rationale
    - 10% doing, 90% defending
- **Knowing what needs to be known when**
  - Research claims can’t know when milestones can be met since unsure if experiment or technology will work
  - Developer’s need for information is based on phase of project
    - Project phase dictates what details need to known when

# Combining Research and Development in the EVA IR Camera Project: Keys to Success

- Project built on thermography expertise of Dr. Bill Winfree and his group
  - 70+ years experience in applying infrared thermography for structural assessment
- Willingness to share knowledge & credit
  - NDE group shared knowledge with development team (no turf battles)
  - Recognized development of flight-hardware not in group charter (let others drive)
- Development team focused on delivery of capable, flight hardware within given schedule and budget
  - Gained sufficient measurement expertise (enough to make credible decisions regarding on-orbit measurement)
  - Provided “drive” to accomplish project goals
  - Provided flight project discipline: on-time and within budget
  - Provided technical expertise across all disciplines
  - Solid risk management: addressed key technical issues early with testing (relied on testing more frequently than review/analysis)
- Established collaborative, team environment
  - OK to make mistakes (focus on how to correct, not why or who)
  - Shared credit – team success, not individual (egos checked at the door)
  - Common vision: “Provide Charlie and STS-114 Crew with Critical Capability ”

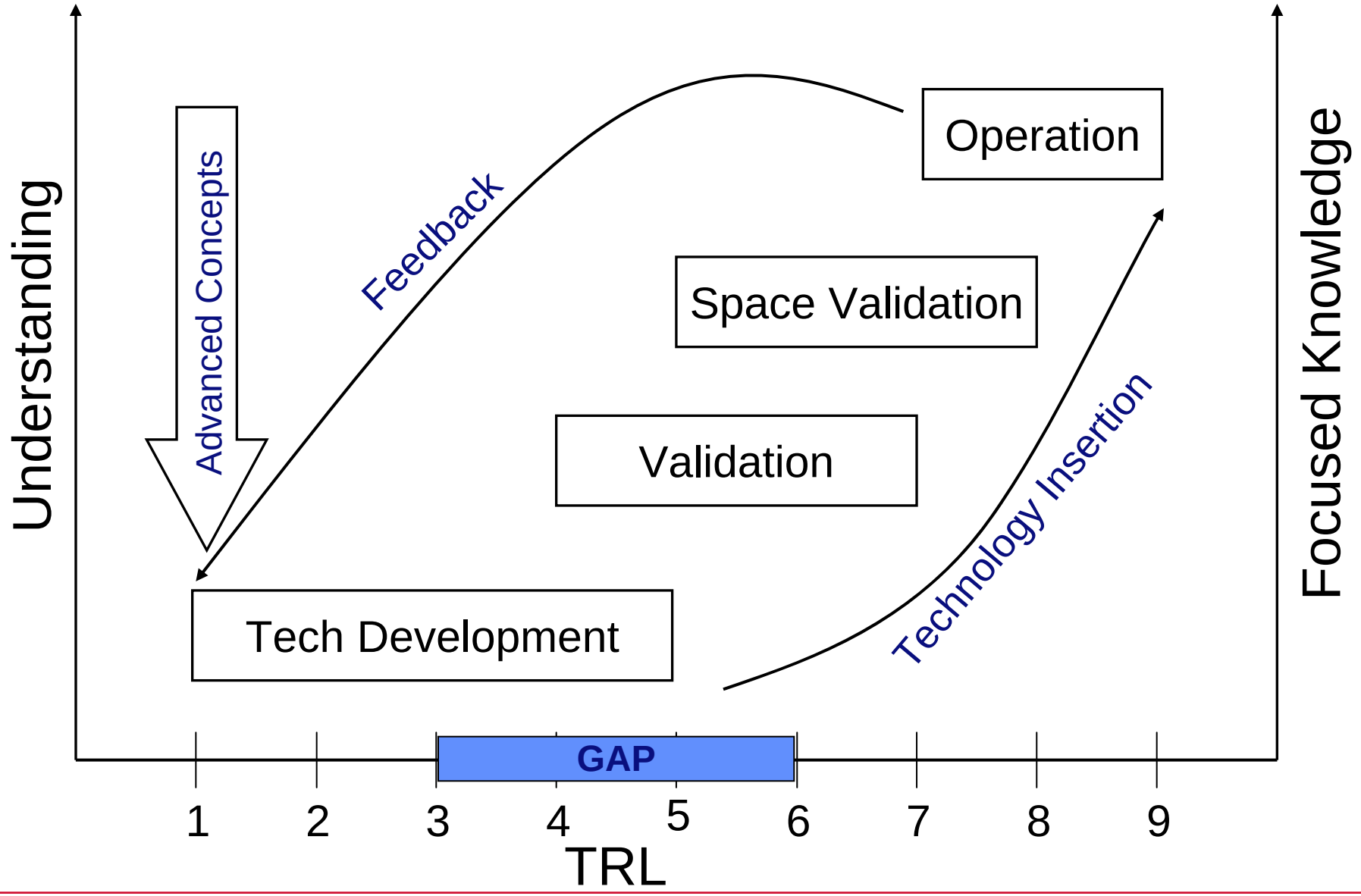
# Bridging the Gap

- What is expected of researchers for the project
  - Application expertise
  - Technology expertise
  - Material expertise
  - How to test, measure, develop component or system

- What is expected of developers for the project
  - To know enough to meet technical goals of the project at an acceptable risk

- What has to happen
  - Researchers need to understand, or at least appreciate, the limited and focused knowledge that developers require
    - Let others “drive”
  - Developers need to understand, or at least appreciate, the application and technology
    - Need to pass the exam

# The Gap in Terms of TRL: Technology or Application

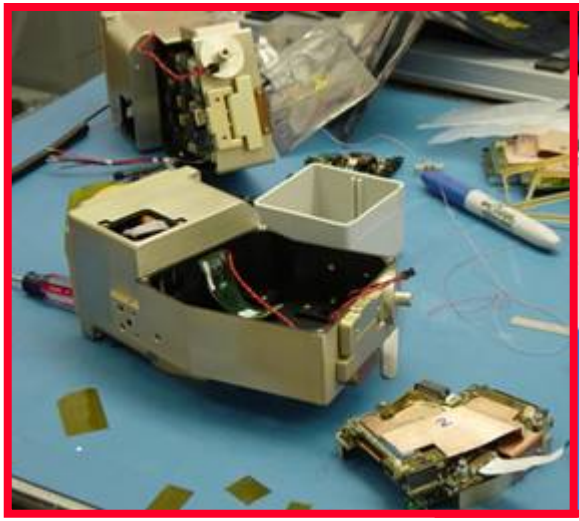


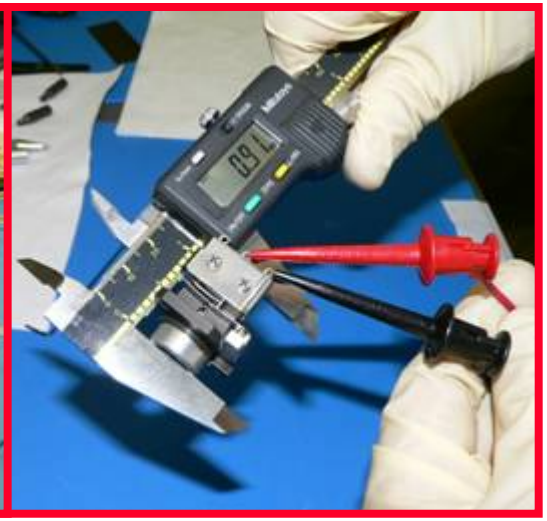
# EVA IR Camera Technical Keys to Success

- Retired functional risks early with environmental testing of off-the-shelf camera system
  - Thermal, vacuum, and radiation testing validated use of commercial system
  - Camera system is relatively small, and fairly inexpensive to test
- Mitigated operational risks early with frequent crew evaluations
  - Two Blue room tests and three NBL runs
  - Provided feedback on how to simplify camera operation
  - Led to clear requirements for firmware changes (to be made by FLIR in Sweden)
- Obtained support from FLIR early in project
  - Trip to FLIR in early January and frequent telecons and email led to solid understanding of project, required changes
  - Contract negotiations went smoothly
- Environmental testing of engineering unit, though later than projected, provided further confidence in performance of system
- Requirements were clear, verifiable, and static
- High level of flight-hardware experience on team led to solid, flight-certified design
- High-level support of Safety Reviews
  - Project manager and Development manager wrote majority of RAESR and presented at SMART reviews
- Majority of team worked nights, weekends, and holidays from October through July

# Internal Fabrication Capability Enabled Delivery

- In-house Fabrication Capability Saved ~3 Months
- Fabrication Technician part of Design-Team
  - Design for build
  - Increases chance parts fabricated right the first-time
  - Part is known before it is built
- 1400 Fabrication Hours
  - About 50% for modifications





- Coordination of Resources
  - Ability to set priority of machining operations and meet project schedule

# Summary

- Bridging the Gap results in stronger, more capable solutions
- Addition of new technology or application results in better systems, better tools for the Agency
- Expense is often inefficiency and communication to bridge cultural differences
- Agency becomes stronger
  - developers understand technology
  - researchers understand development process
  - everyone passes the 7120.5D exams, and the technology exams